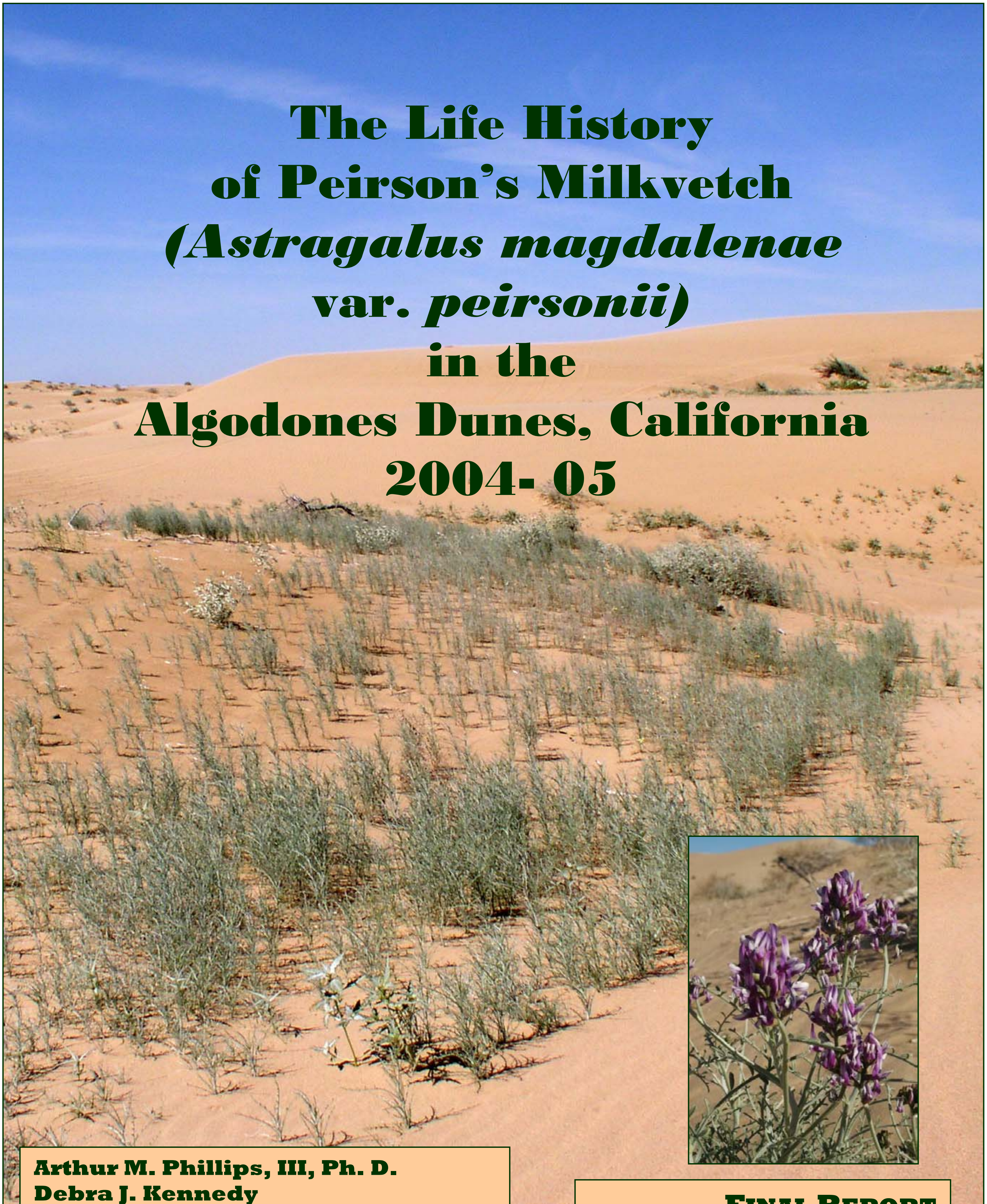
The Life History of Peirson's Milkvetch (*Astragalus magdalenae* var. *peirsonii*) in the Algodones Dunes, California 2004- 05



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FINAL REPORT

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INTRODUCTION

Winter rains began early in the Algodones Dunes in the 2004-05 growing season, starting with a storm on October 22nd that left 1.3 inches of rain at Buttercup and 0.88 inches at Cahuilla. Rainfall continued at regular intervals through early March, providing growing conditions favorable for germination of seeds and robust growth of perennials.

This report summarizes findings from a fifth year of studies on the ecology, phenology, and demography of *Astragalus magdalenae* var. *peirsonii* (Peirson's milkvetch), a short-lived perennial in the Legume family (Fabaceae) that is widely distributed in clustered populations throughout the Algodones Dunes complex. It was listed as a Threatened species in 1998 (USFWS 1998, CNPS 2001, BLM 2000a) and has been the focal point of a number of legal and administrative actions, especially since the fall of 2000. Despite the listing, little information was available on the plant's biology; thus, the American Sand Association has funded a multi-year research project in order to learn more about the ecology of this desert plant and its interactions with off-highway vehicles (OHVs**),** with which it shares the Algodones Dunes.

The Algodones Dunes are a complex of sand dunes located in southeastern Imperial County, California and extending a short distance into adjacent Baja California, Mexico. They support a specialized, limited biota that has adapted to the severe conditions posed by an ever-changing habitat with low, unpredictable rainfall, severe annual and diurnal temperature extremes and occasional severe abrading wind-carried sand. Many of the plant species found in the dunes are endemic to sand dunes in the Lower Colorado Valley subdivision of the Sonoran Desert (Bowers 1986; Shreve 1964). Among these is Peirson's milkvetch.

Research Area

An overview of the geologic history and setting of the Algodones Dunes is provided by Norris and Norris (1961). The system consists of a complex chain of overlapping barchan dunes, with the higher dunes rise 60-90 m (200-300 feet) above the desert floor. From west to east a series of sand ridges along the western edge gradually transition to the highest, most active dunes (generally the focal point of OHV recreation) in the eastern half of the system. Between the ridges and the high dunes are a series of lower bowls and ridges, which support the highest levels of vegetation density, including Peirson's milkvetch.

The Algodones Dunes are about 65 km (40 miles) in length, trending from northwest to southeast, and from 5 to 10 km (3 to 6 miles) wide (see Figure 1 below). The total area of the dune system includes approximately 60,705 ha (150,000 acres), of which 10,730 ha (26,500 acres) were designated as a wilderness area in 1972 (BLM 2000b). Temporary administrative closures of an additional 20,000 ha (49,000 acres) were imposed in November 2000 as a lawsuit settlement over protection of Peirson's milkvetch.

Off-highway vehicle (OHV) recreational use of the Algodones dunes complex has been occurring for several decades. There has been a substantial increase in OHV popularity in the past 25 years, however, with mushrooming use levels in the past decade due to the introduction of a wider variety of vehicles of increasing sophistication. Although there has been some speculation that increasing levels of OHV use within the dune system negatively affect the status of *A. m.* var. *peirsonii*, it is important to note that *no scientific, empirical study examining the actual impact of OHV use on Peirson's milkvetch (along with other plants and animals in the dune system) has yet been completed.* Thus, the primary purpose of this long-term research project is to address the critical gap in our collective knowledge of a crucial desert plant.

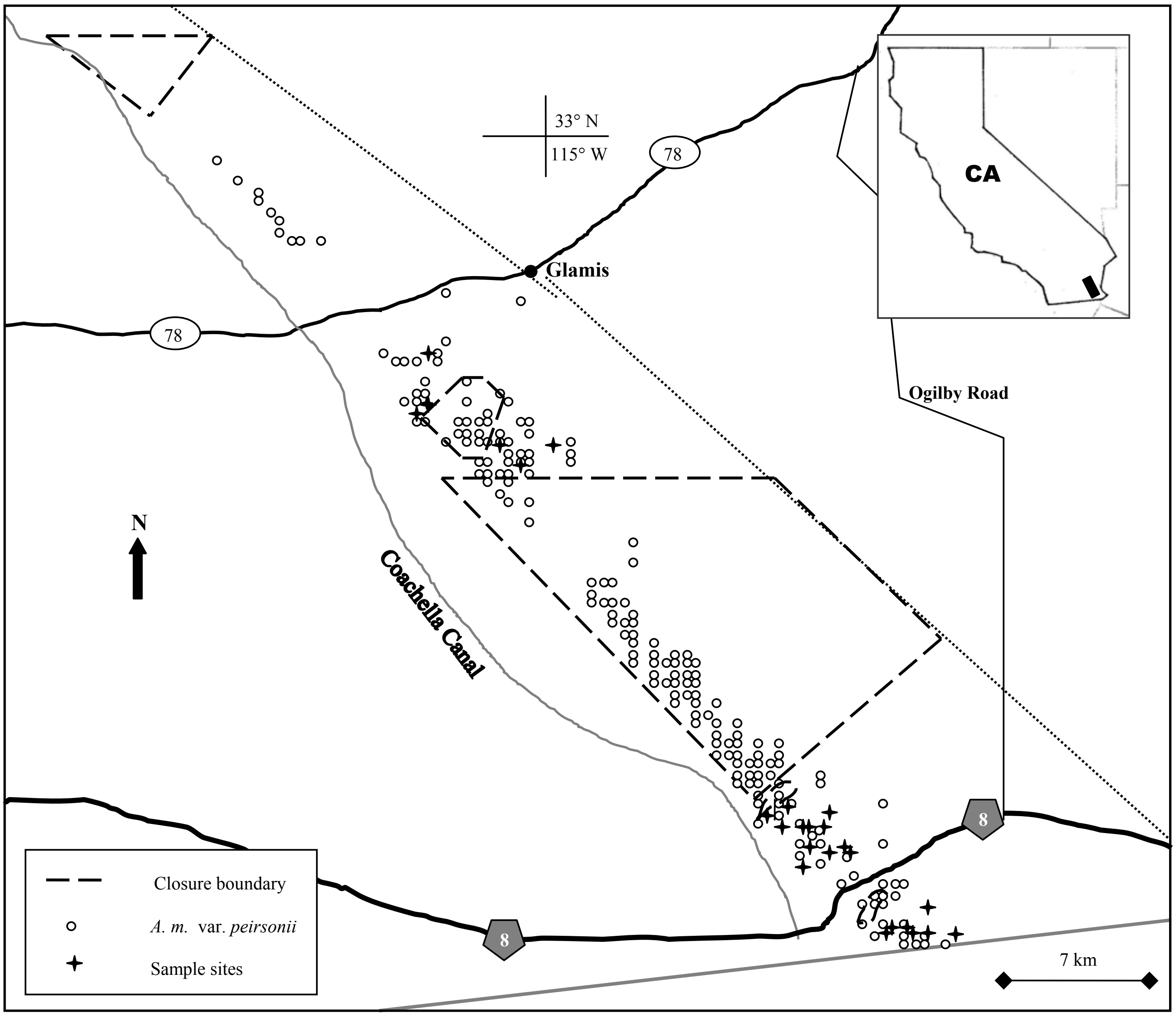

Figure 1. Distribution of *Astragalus magdalenae* var. *peirsonii* sites in the Algodones Dune system initially surveyed in spring 2001, sampled in winter 2001-02, and re-sampled in all subsequent studies[1]

[1]Site locations are approximate; see Phillips et al. (2001) Appendix A for exact geo-coordinates. Locations within the closure areas were mapped by helicopter survey.

METHODS

The 2004-05 growing season marked a fifth year of study of the *A. m.* var. *peirsonii* population, distribution and ecology in the Algodones Dune system. As previously noted, the 2004-05 season received abundant rainfall resulting in the largest germination event we have yet documented for this plant. This report provides another year of cumulative scientific data, compiled through ten individual studies conducted over a five-year period (2001-2005), on the ecology and life history of this important desert plant. Our initial study, conducted in 2001, included the mapping and documenting of known Peirson's milkvetch distribution and population throughout the entire dune system (see Phillips et al. 2001). Subsequent studies, including those conducted in 2004-05, have focused on a 40% sample of sites identified in the initial 2001 survey as areas of known plant occurrence, randomly selected and stratified by location in the dunes complex (Phillips and Kennedy 2002).

As previously noted, when this research project began in early 2001, there was little literature available on the ecology of *A. m.* var. *peirsonii*, as few scientific studies of the species had been conducted. The over-riding purpose of this multi-year project is to compile empirical data in order to address several basic research questions on the status of *A. m.* var. *peirsonii*. These include:

- What is the population status of *A. m.* var. *peirsonii* in the Algodones Dune complex?
- How are the plants distributed, both within the dune system and within individual sites of occurrence?
- Are Pierson's milkvetch clusters self-perpetuating?
- Under what conditions are plants most or least likely to germinate and thrive?
- How significant is time of germination to the ability of the plants to reproduce?
- Are first-year plants able to reproduce?
- What is the survivorship rate of plants over time?
- What is the impact of OHV use on the status of the species?
- What is the status of the seed bank?
    - What is its overall size?
    - How many seeds does an average plant produce in one year?
    - How long do the seeds remain viable?
    - How are seeds dispersed?
    - Are there predation impacts on the seed bank?
    - Where in the substrate does germination occur?
- Do viable populations of *A. m.* var. *peirsonii* exist outside the Algodones Dune complex?

Over the course of this project, various methods have been adopted to address these questions. Study methods and protocols included in this research agenda evolved from prior findings; thus enabling us to establish a valid scientific framework from which we base our conclusions. The following is a brief overview of the methods and findings of our work.

Year One – Habitat, Distribution, Population and Reproduction

In order to evaluate the population, distribution, reproductive capabilities and habitat requirements of *A. m.* var. *peirsonii* during year one of our study, we employed a number of observational techniques. Statistical sampling methods were not included in this stage of the investigation, since the purpose of this initial survey was to locate as many occurrences of the subject plants as possible, and to completely census and document reproductive and habitat data from every area in the dune system in which they were found.

A preliminary reconnaissance of the dune complex was conducted in 2001 from the U.S.–Mexico border north to California Highway 78 (the southern boundary of the wilderness area) covering approximately 14,165 ha (35,000 acres), or 59% of the open area of the dune system. From data collected during this reconnaissance, we determined that *A. m.* var. *peirsonii* generally occurs in highly clustered, specialized habitats within the dunes, and that a large portion of the dune system (approximately 70-75%) does not contain habitat suitable for these plants. Using data gathered from the reconnaissance and informant interviews, along with our specific knowledge of habitat requirements, we selected several areas for concentrated surveys for the presence of the subject plant.

When *A. m.* var. *peirsonii* plants were present in an area, it was designated a “site,” a number was assigned to that area and a complete census of plants was conducted. The location and circumference of each site was recorded using Global Positioning System (GPS) technology. Any area of occurrence that was too small to circumscribe, or that contained a single cluster of *A. m.* var. *peirsonii*, was designated a “point.” The plants contained within a point were also censused and their location documented. Utilizing this methodology, we identified and mapped 60 sites and 66 points of Peirson’s milkvetch occurrence, and documented an actual total of 71,926 plants. Of these, approximately 45% were determined to be reproductive. Both site and point data were mapped and entered into a master database (Phillips et al. 2001, Appendix A).

An aerial (helicopter) reconnaissance of the 30,567 ha (75,000 acres) within the three temporary closure areas and the wilderness area allowed us to map the distribution of Peirson’s milkvetch utilizing GPS technology. No census of plants was possible from the air but 185 points of milkvetch occurrence were mapped (see Phillips et al. 2001, Appendix B).

Year Two – Seed Bank Viability and Plant Survival

The data gathered during the first year of study showed a high degree of non-random distribution of Peirson’s milkvetch within the dune system; i.e., the plants were distributed in particular similar locations, and clustered within the habitats where they were found. Additionally, results of the 2001 survey showed significant diversity of plant population and density between three general areas of Pierson’s milkvetch distribution within the dune complex -- possibly due to differences in habitat, rainfall, temperature and/or OHV use. Thus, in order to account for this variance and adequately represent the target population, we stratified the 60 sites of known plant occurrence into three locations. Location 1 encompasses most of the open area of the dune system south of Interstate 8 and north of the international border, known as the Buttercup area. Location 2 includes the area north of Interstate 8 and south of the large central closure (Patton Valley). Location 3, in the northern region of the system, includes the open area from south of Highway 78 and east of Gecko Road to the northern boundary of the large central closure. From each location, we randomly selected 40% of the sites for sampling in year two; thus, seven sites were selected in location 1, twelve in location 2 and six in location 3, for a total of 25 sample sites. According to the literature, this sampling method is best suited for the study of clustered populations (see Phillips et al. 2001 for full discussion). Additionally, stratified random sampling is common practice in natural resource sampling. Utilizing this method, density and population estimates are calculated separately for each location (i.e. – "stratum"); thus, each sampling location is treated as if it were a simple random sample (see Schreuder et al. 2004, cited in BLM 2005:3).

Year two of the study was conducted from November 2001 to February 2002 and data on the *A. m.* var. *peirsonii* October 2000 cohort survival rates and seed bank viability were collected, documented and analyzed. The purpose of the soil seed bank study was to provide an estimate of the number of seeds in the seed bank in order to assess the potential status of the population, and to determine patterns of spatial and temporal seed distribution. The purpose of the 2000 cohort survival census was to determine the viability and reproductive capability of Pierson's milkvetch from one growing season to another (given summer temperature extremes).

Both seed and 2000 cohort survivor population estimates were made based on actual counts at each sample site per location, then extrapolated to all the sites of known plant occurrence (identified in 2001) at each location. Analysis of the second year of data shows a seed bank population of 2.5 million (using actual counts of reproductive plants only) to 5.6 million (using actual counts of the total number of plants) *A. m.* var. *peirsonii* seeds. The estimate of the 2000 cohort survivorship to winter 2001-02 was determined to be approximately 21% (see Phillips and Kennedy 2002 for full discussion of results).

Years Three and Four – Population, Reproduction, Germination and Survival

Year three studies were conducted from March to May 2003 and included a third-season census of the survival and reproductive rates of the 2000 cohort plants at the 25 sample sites, and a census of a new seedling cohort group that had germinated in late February 2003. Results of this study are presented in Phillips and Kennedy (2003).

The fourth year of this project included four separate studies of Peirson's milkvetch population and status, beginning in October 2003 to April 2004, during which we were able to document two germination events (November 2003 and February 2004), as well as gather data on perennial survivors at our 25 sample sites. Additionally, we were able to observe, document and compare the viability of two groups of germinant cohorts through a single growing season to determine how critical time of germination is to the ability of *A. m.* var. *peirsonii* to reproduce. A comprehensive analysis and discussion of the results of year four studies are found in Phillips and Kennedy (2004).

Year Five – Documenting a Major Germination Event

The fifth year of research on the status of *A. m.* var. *peirsonii* included four Algodones Dunes studies and a survey of Anza-Borrego State Park to determine if a viable plant population exists outside the dunes complex. During each of the dunes studies, a census of the plant population at each of the 25 sample sites was conducted in the same manner as in prior years. Population counts were delineated based on fertility, the age class of plants was determined whenever possible, and data were recorded in field using both field forms and GPS technology (see Appendices B and C for examples of in-field data forms used in the 2004-05 studies). Additionally, plant "clusters"[2] that had been documented and mapped at each of the sample sites in 2002 were revisited to determine whether Pierson's milkvetch clusters are self-perpetuating (see Appendix D).

A survey of dune areas in Anza Borrego Desert State Park was conducted by Vincent Brunasso in an attempt to locate an old, undocumented locality for *A. m.* var. *peirsonii.* We (Phillips, Kennedy, and Brunasso) visited one small population along the eastern edge of the park in December 2004, when about 30 seedlings were present. It was re-visited by Dr. J. Mark Porter of Rancho Santa Ana Botanic Garden in March 2005; he reported about 22 plants, with eight individuals in flower. He confirmed the identification as Peirson's milkvetch but did not consider it to be a viable population because of the small number of plants and possible lack of genetic diversity (personal communication, J. M. Porter to V. J. Brunasso, 17 March 2005). No additional occurrences of Peirson's milkvetch were found in Anza Borrego. We also carried out negative searches for *A. m.* var. *peirsonii* in the Mohawk Dunes, Yuma County, Arizona; a small area in the northwestern portion of the Gran Desierto dunes in northwestern Sonora, Mexico; and V. J. Brunasso searched the Kelso Dunes, California, and dunes east of Anza-Borrego.

A. m. var. *peirsonii* density and population estimates are based on sample site values. Density values are calculated individually for each location and population estimates extrapolated only to those sites of known Peirson's milkvetch occurrence at each location. Thus, the mean plant density (plants per square meter) of seven sites at Buttercup is extrapolated to the 17 Buttercup sites originally identified in 2001, the mean plant density of 12 sample sites at Patton Valley is extrapolated to the 27 original Patton Valley sites, and so on. This method is highly consistent with natural resource sampling methodology, and was recently adopted for the 2004 BLM survey of special status plants in the Algodones Dunes complex (BLM 2005). Our population estimates, however, are much more conservative than those reported elsewhere (see BLM 2005), since we extrapolate plant density data only to *known and documented sites of plant distribution* -- a total area of approximately 56 ha, or 0.9% of the potential habitat of *A. m.* var. *peirsonii.*

Upon completion of the 2004-05 fieldwork, data were analyzed using SPSS version 11.0 statistical software (SPSS 2001). Precipitation and survivorship graphs were produced with Microsoft Excel 2002; all other graphs and charts were constructed with SPSS.

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[2] A "cluster" is defined as a minimum of 20 plants growing within a $70m^2$ area. During the 2002 seed bank study, all PMV clusters at each of the sample sites were mapped using GPS technology, and one cluster from each site was selected for study.

RESULTS AND DISCUSSION

Rainfall and germination were greater in the 2004-05 season than in any other of the five years of this study. The first year of the project, March 2001, was a season of abundant Peirson's milkvetch growth and reproduction; however, the 2004-05 rainfall resulted in approximately 2.5 times the number of plants that were recorded at the same sites in 2001.

The first rainfall of the season occurred October 21-22, 2004, resulting in 1.3 inches of precipitation recorded at the Buttercup RAWS weather station and 0.88 inches at the Cahuilla Ranger Station. Our first survey of the season was November 4-6, followed by December 17-20, 2004, March 12-15, 2005, and April 14-17, 2005 studies. This allowed us to observe and document a germination event that occurred from October through December 2004 and to assess the survival and reproductive success of the 2004 cohort germinants to March and April 2005.

In addition to 2004 germination data, data on the survival and the reproductive status of adult plants documented in previous years' studies were recorded in November, December, and March. These data enabled us to determine how many of the fertile plants observed in the 2004-05 season were first-year plants and how many were second-year and older. A summary of data collected in the 2004-05 studies is in Appendix A of this report.

Population and Distribution

The results of population studies conducted during the fifth year of this project show an actual count of 77,922 live *A.m.* var. *peirsonii* documented at our 25 sample sites in March 2005, and 66,931 plants in April. These values were subsequently analyzed with an SPSS statistical program to determine average plant density per location (number of plants per square meter). The results are presented in Figure 2.

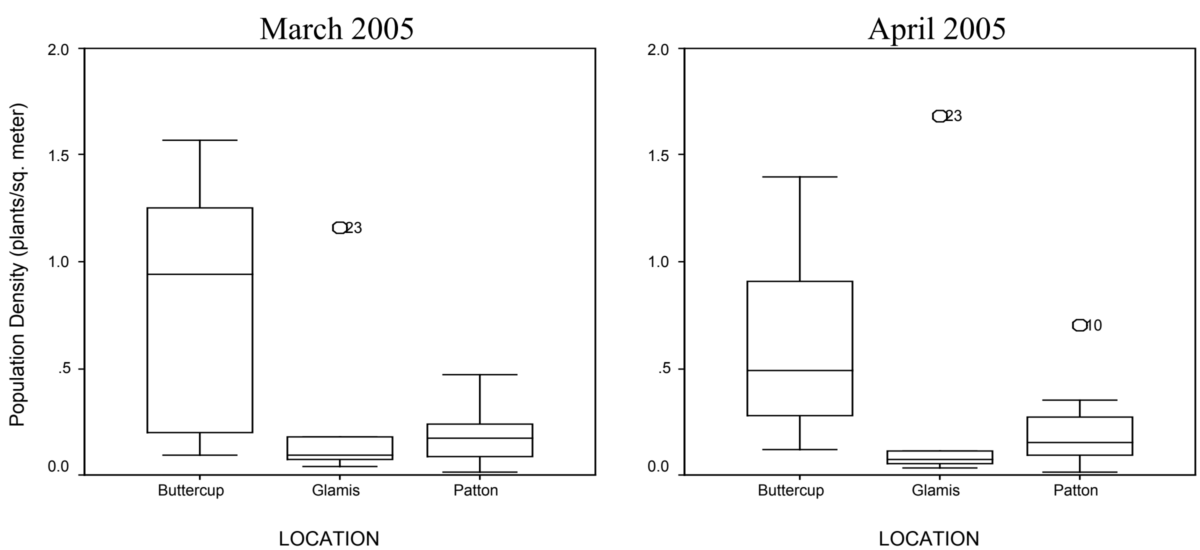


Figure 2. March and April 2005 plant density (plants/m^2)
25 sample sites at three locations

As evident in Figure 2, one sample site value (at Glamis) in March and two values (one each at Glamis and Patton Valley) in April are clearly outliers; thus they have the potential to skew our data. Therefore, population estimates are calculated two ways – one with all sample site values included, and a second with the outliers removed. In so doing, we feel that we are presenting the most conservative and valid population estimates possible. The results are presented in Table 1 and Figure 3.

PMV Population Estimates Per Location March 2005

	Population (actual count)	$Density_1$ (μ PMV/m^2)	$Range_1$	Std. $Dev._1$	**Population $Estimate_1$**	$Density_2$ (μ PMV/m^2)	$Range_2$	Std. $Dev._2$	**Population $Estimate_2$**
Buttercup	41,626	0.7857	1.48	0.616	**94,166**	0.7857	1.48	0.616	**94,166**
Patton Valley	34,284	0.1858	0.19	0.438	**76,483**	0.1858	0.53	0.147	**76,483**
Glamis	2,012	0.3772	0.53	0.156	**10,748**	0.9400	1.12	0.48	**2679**
Totals	**77,922**				**181,397**				**173,328**

Population $Estimate_1$ based on extrapolation of mean plant density at all sample sites
Population $Estimate_2$ based on extrapolation of mean plant density with one outlier removed

PMV Population Estimates Per Location April 2005

	Population (actual count)	$Density_1$ (μ PMV/m^2)	$Range_1$	Std. $Dev._1$	**Population $Estimate_1$**	$Density_2$ (μ PMV/m^2)	$Range_2$	Std. $Dev._2$	**Population $Estimate_2$**
Buttercup	31,550	0.6271	1.28	0.485	**75,184**	0.6271	1.28	0.485	**75,184**
Patton Valley	33,523	0.1950	0.34	0.109	**80,270**	0.1582	0.59	0.164	**65,121**
Glamis	1,858	0.3367	0.08	0.032	**9,594**	0.0680	1.65	0.659	**1,938**
Totals	**66,931**				**165,048**				**142,243**

Population $Estimate_1$ based on extrapolation of mean plant density at all sample sites
Population $Estimate_2$ based on extrapolation of mean plant density with two outliers removed

Table 1. March and April 2005 population estimates for 60 sites at three locations, based on mean plant densities per location (including and excluding outliers)

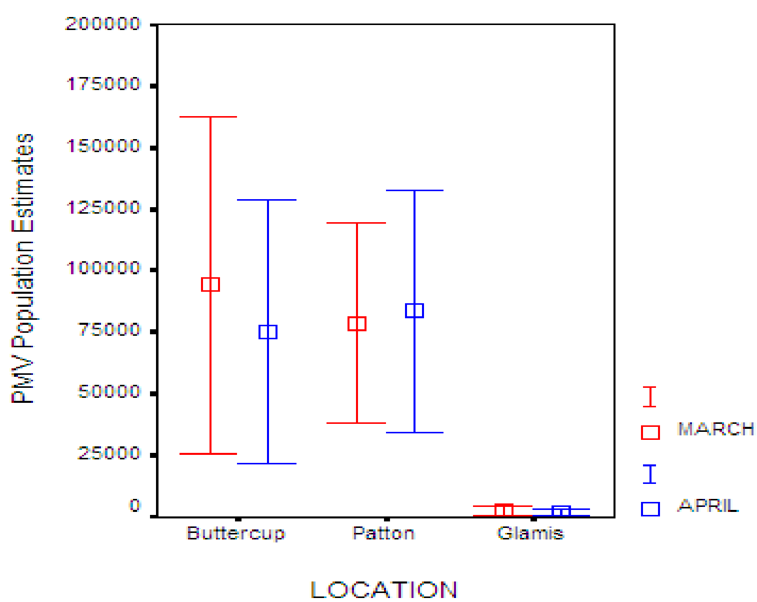


Figure 3. March and April 2005 population estimates (excluding outliers) per location. Bars represent 95% Confidence Intervals

Based on the results of the 2004-05 population studies, the approximate population of *A.m.* var. *peirsonii* present within 56 ha of the plant's potential habitat in the Algodones Dunes in March and April 2005 was (at a minimum) 173,328 and 142,243 plants respectively.

In addition to population studies, the fifth year of research on this project also included examination of plant distribution within specific sites in order to address the research question: Are plant "clusters" self-perpetuating? Although previous years' studies included observations of a number of the plant clusters documented at each sample site in 2001-02, a concerted effort was made in March 2005 to fully document (count the number of plants present) all plant clusters in the sample areas that had been mapped in the 2001-02 study. Thus, using GPS geo-coordinates and maps produced in 2002, each cluster was re-surveyed in 2005, and data were entered into a special field form (see Appendix D). The results are shown in Table 2.

Buttercup				**Patton Valley**				**Glamis**			
Site#	*#Clusters 2002*	*#Clusters 2005*	*Population Increase?*	*Site#*	*#Clusters 2002*	*#Clusters 2005*	*Population Increase?*	*Site#*	*#Clusters 2002*	*#Clusters 2005*	*Population Increase?*
6	1	2	Y	32	4	2	N	13	3	3	Y
7	4	5	Y	34	3	3	Y	15	1	1	Y
21	3	5	Y	41	3	3	N	16	1	0	N
22	5	4	N	44	2	3	Y	19	1	2	Y
23	5	5	Y	46	5	5	Y	60	1	0	N
28	3	4	Y	47	5	7	Y	61	1	1	N
29	4	4	N	48	3	3	Y				
				51	8	9	Y				
				52	5	5	N				
				53	4	4	Y				
				54	4	5	Y				
				57	4	4	Y				
Total	**25**	**29**	**Y**	**Total**	**50**	**53**	**Y**	**Total**	**8**	**7**	**Y**

Table 2. Results of plant cluster self-perpetuation survey, March 2005. Population increase refers to total number of plants in clusters, not to increase in number of clusters.

As these results indicate, clusters of *A.m.* var. *peirsonii* are clearly self-perpetuating, and, as in the case of two of the three locations surveyed, potentially re-generating after long periods of dormancy-- given proper conditions, such as adequate precipitation and temperature.

A second conclusion we were able to draw from this and prior years' research is that an individual plant cluster may completely die off during dry years, yet re-generate when conditions are appropriate. For example, fours years of cumulative data on a single plant cluster mapped and documented in February 2002 at Site 53 (Patton Valley) show an initial cluster of approximately 30 fertile plants in a 70m^2 area. In November 2003, most of the adult plants were dead, but a small number of seedlings were observed. By December 2003, however, all the plants in the cluster were dead or missing, but 53 seeds were noted on the surface of the soil. In November 2004, the area included a large cluster of seedlings; finally, in March 2005 that single plant cluster at Site 53 contained 35 fertile and 10 non-fertile first-year plants. The above example is one of several documented throughout the five-year course of this research project, which help to shed light on the status and viability of this important desert species.

2004-05 Germination

As noted above, a series of rainfall events beginning on October 21, 2004 resulted in the largest germination event recorded in the past five years for Peirson's milkvetch in the Algodones Dunes complex. Table 3 summarizes the actual counts of first-year plants documented at the sample sites (by location) during the four studies conducted in 2004-05.

	Nov. 04	*Dec. 04*	*Mar. 05*	*Apr. 05*
Buttercup	10,065	30,797	41,626	31,550
Patton Valley	8,377	24,126	34,282	33,523
Glamis	385	895	2,012	1,858
Total	**18,827**	**55,818**	**77,920**	**66,931**

Table 3. Numbers of seedlings/first-year plants at 25 sites in three areas of the Algodones Dunes at four sampling periods during the 2004-05 growing season

These values only refer to plants that germinated during the 2004-05 growing season; a discussion of second-year survivors and perennial plants is in the following section. As noted in Table 1, numbers of plants in each area increased substantially at each of the visits through March 2005. This is likely due to the fact that the amount and timing of rainfall from October through early March was such that the sand maintained continuous moisture within a centimeter or two of the surface, resulting in germination of Peirson's milkvetch seeds for an extended period during the growing season. Thus, in November, about two weeks after the initial rains, a total of 18,827 seedlings were counted. At the December visit, two months after the first rains and after three subsequent storms, 55,818 or nearly three times as many seedlings were counted. There was no means of aging plants, as there was a continuum of sizes. Apparently microsite differences play a greater role than age in determining size. The lack of any obvious size stratification, which would indicate bursts of germination after each storm, suggests that germination was essentially continuous.

Two storms in January and a major storm the third week in February kept the sand moist, and additional germination was noted at the March visit, resulting in a total of 77,920 plants counted and documented at our 25 sample sites. At that time some of the early first-year plants were already in fruit, having apparently flowered in January or early February, and it was not otherwise possible to distinguish early season germinants from later season seedlings. Still unresolved is the question as to whether germination occurs in the "dead of winter," from late December through early February; this question remains elusive as there was not an obvious two-tiered size class distribution of plants noted in 2004-05 that would have suggested separate germination times.

By the mid-April study, the numbers of plants started to decrease, and many were observed to be dead and dying from lack of water. Among these were some that had been in fruit in March, indicating that some first-year plants successfully reproduce even though they may not survive through spring of their first season. The last significant rainfall at both Buttercup and Cahuilla was on March 5th, and the depth to moist sand was much greater in April (20-30 cm vs. 2-5 cm in March), which, coupled with strong drying winds in April and higher temperatures, apparently caused the desiccation and death of up to 15% of the plants present at the time of the maximum plants counts in March 2005.

Survival

By the fall of 2004 there were only eight individuals surviving from the fall 2000 and late winter 2003 germination events, and it was no longer possible to determine the age of these plants. Most were large, diffuse, with thick roots (>1 cm in diameter), and flowering by December. The number of perennial survivors was so small by March 2005 that we discontinued counting them, and included them in a single count of "perennials" which included plants that germinated during the 2003-04 season. Table 4 summarizes counts of perennials and second-year plants in December, 2004. At that time, the number of surviving 2003-04 germinants present was 1,168; the count of these plants in March 2004 was 9,848, for a survival rate of 12% through the summer of 2004.

	#Perennial Survivors Dec. 04	*#2003-04 Survivors Dec. 04*
Buttercup	1	188
Patton Valley	3	933
Glamis	4	47
Total	**8**	**1,168**

Table 4. Number of perennial and second-year survivors at 25 sample sites in three locations of the Algodones Dunes, documented in December 2004.

A graph showing survivorship curves for the 2000, 2003, 2004, and 2004-05 cohorts is shown in Figure 4 below. This log-base 10 chart shows the sharp reduction in plant numbers during the summer, notably for the 2000 cohort in which the reduction (79%) was tempered by summer rains, and for the 2003 cohort (reduced by 99.7%), which germinated in February and did not have any rainfall during the ensuing summer. The 2003-04 cohorts (November and February) also had rainfall in late summer 2004, but there were also losses in the November-germinating plants due to drought conditions in mid-winter. Reductions in numbers of the fall 2004 cohort occurred between March and April, after the last rainfall event; numbers were actually higher in March (not shown on graph) than in December (the data point plotted on the chart).

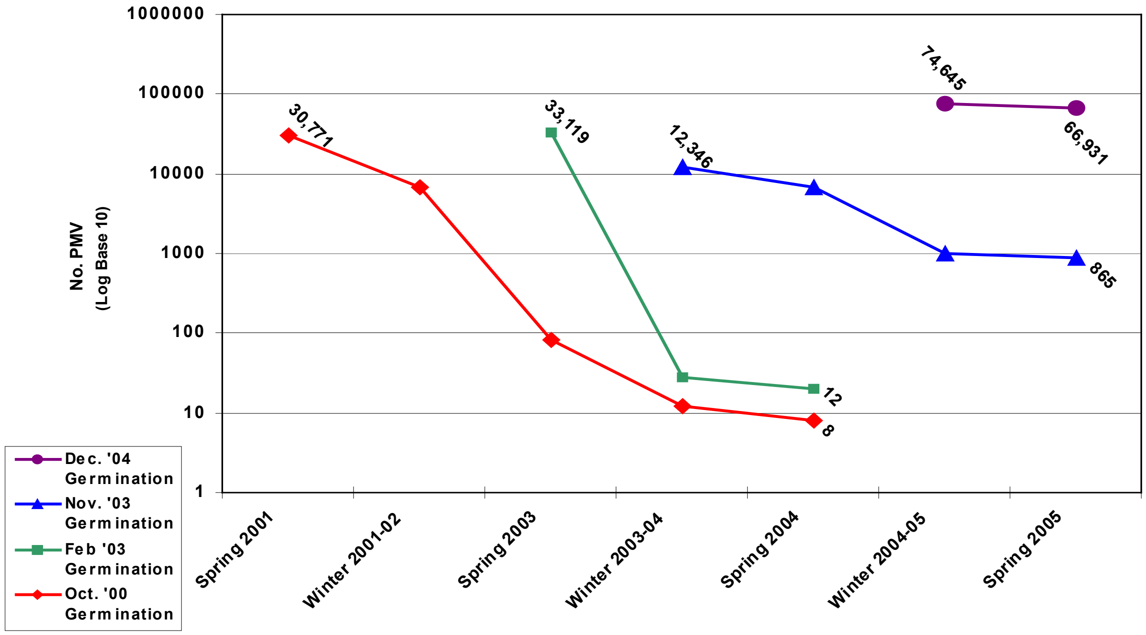


Figure 4. Survival of 2000, 2003 and 2004 germinants to spring 2005 at 25 sample sites

It has been argued elsewhere that we have incorrectly identified age classes in prior studies; i.e., that we have been unable to distinguish between first-year and second-year plants (see Porter 2003, USFWS 2003a, 2003b, 2004). We use here survival figures for December when two-month-old seedlings were clearly distinguishable from second-year (2003-04) and older survivors. The proportion of seedlings to survivors in December was 48:1; in March it was 67:1 (using the December figure of 1,168 for number of survivors). Clearly, in the spring of 2005 the number of first-year plants far exceeds the number of second-year and older plants. This issue will be considered further in the discussion of reproduction, in the following section.

2005 Fertility and Seed Production

Separate counts of fertile and non-fertile plants were made in March and April 2005 (Table 5). In March, plants that had fruits, flowers, or buds were considered to be "fertile." In April, however, we were concerned whether later germinants were likely to actually produce seeds; thus we counted only plants that had flowers or pods. Because of dry, hot conditions in the four weeks between trips, many plants that had immature fruits in March had already shed their pods in April and appeared to be "sterile." In addition, a number of plants had died from desiccation in April. Thus both the proportion of fertile plants and the total number of plants decreased in the April study. We do not know how many of the plants that were in bud in March went on to produce fruits in April, or how many of the early-fruiting plants appeared to be sterile in April. Therefore, the most conservative figure for first-year plants that reproduced successfully among our 25 sample sites in 2005 is 19,945. As stated above, the number of perennial survivors to spring 2005 was 1,168. Assuming that all of the survivors successfully reproduced, we conclude that there were at least 17 times as many first-year as second-year plants that reproduced in the spring of 2005.

	#2004-05 Plants. Mar. 05	#2004-05 Plants Fertile Mar. 05	#2004-05 Plants Apr. 05	#2004-05 Plants Fertile Apr. 05
Buttercup	41,626	22,959	31,550	7,296
Patton Valley	34,284	24,603	33,523	11,549
Glamis	2,012	1,396	1,858	1,100
Total	**77,922**	**48,958**	**66,931**	**19,945**
% Fertile		**62.80%**		**29.80%**

Table 5. Total number of Peirson's milkvetch plants counted in March and April 2005 at sample sites in three locations, and the percentage of fertile plants at each.

These data establish conclusively that first-year plants are able to reproduce during their initial growing season *if they germinate in the fall.* Our studies in 2002-03 and 2003-04 showed that late winter germination events of significant size can occur with rainfall between mid-February and mid-March, but these late season plants do not reproduce during their first year (Phillips and Kennedy 2003, 2004). The results of the 2004-05 study confirm that Peirson's milkvetch exhibits a dual reproductive strategy -- plants that germinate in late fall are capable of reproducing in the spring of their first year, while plants that germinate in late winter remain sterile during the ensuing spring, and the survivors flower during the second year.

Finally, using the most conservative count of fertile plants at our sample sites (April 2005), along with data gathered in prior years' studies, we were able to estimate the spring 2005 fertile plant population and its approximate contribution to the soil seed bank among our original 60 survey sites (totaling approximately 56 ha of the potential *A.m.* var. *peirsonii* habitat in the Algodones Dunes). The results are shown in Table 6.

Fertile Population Estimates and Seed Production Per Location April 2005							
	Population (actual count)	Density (μ PMV/m^2)	Range	Std. Dev.	**Population Estimate**	Seed Production* (μ seeds/plant)	**Seed Production Estimate**
Buttercup	7,296	0.1657	0.31	0.107	**19,866**	54.8852	**1,090,349**
Patton Valley	11,549	0.0675	0.23	0.062	**27,786**	79.8640	**2,219,101**
Glamis	1,100	0.1250	0.60	0.238	**3,562**	34.9750	**124,581**
Totals	**19,945**				**51,214**		**3,434,031**

*Seed Production based on results of 2001-02 seed bank survey

Table 6. Fertile Population and Seed Production Estimates at 60 survey sites, based on actual counts of fertile plants at sample sites in April 2005.

Variation in Seed Production

The relative contribution to the seed bank by plants of various ages has been a topic of some debate and confusion. The answer is that it varies from year to year depending on the age structure of the reproductive population. Table 7 presents an estimate of relative seed bank contribution (in number of pods) over the five-year period of this study.

	2001	2002	2003	2004	2005
First-year plants	69,615	0	0	30	99,725
Perennial plants	0	1,096,452	14,193	3420	199,728

Table 7. Seedpod production by first-year reproductive plants and perennials at 25 sample sites, 2001-2005.[3]

The assumed average production of 171 pods per perennial plant is based upon a small sample of plants at one site (Phillips and Kennedy 2003) and does take into account sterile plants or those that produce few pods. Pod production by second-year plants in 2002 (based on a 21% survival rate, or 6,412 plants) is 16 times the production by first-year plants in 2001, but by the third year the 2001 contribution by first-year plants is five times greater than the production of third-year perennials in 2003. In 2004 a few plants that germinated in November 2003 survived mid-winter drought to produce pods the following spring, and the perennial pod production is a combination of survivors from 2001 and second-year plants that germinated in February 2003. The 2005 pod production is based on the April count of 19,945 fertile first-year plants and a December count of 1,168 second-year and older perennials. Although the number of first-year plants is 17 times greater, total pod production is only half the number of pods produced by perennial plants. Over the five-year period, pod production by second-year and older plants totals about eight times the number of pods produced by first-year plants. From this summary it is apparent that the number of seeds produced varies widely from year to year, and the relative contribution of first-year reproductive plants and perennials depends on the year.

Climate, Germination and Survival

The link between climatic events and germination, reproduction, and survival of Peirson's milkvetch has been a primary area of investigation since the start of this project in the spring of 2001. The climatic link between the germination event in the fall of 2000 and rainfall was examined by Phillips et al. (2001). During the first year, it was necessary to utilize remote weather records to correlate germination with precipitation. Data from two Remote Automated Weather Stations (RAWS) installed in November 2001 at Buttercup and Cahuilla Ranger Station has allowed a much more accurate estimate of rainfall within the dune system. Rainfall records from September 2002 through May 2005 are shown in Table 8 below.

[3] Assumes production of 5 pods per plant by first-year plants and 171 pods per plant by perennials, and that 100% of perennials are reproductive.

Date	*Precipitation (in.)*		*#Days*	*Max (in.)*	*Date*	*#Days*	*Max (in.)*	*Date*
	Buttercup	Cahuilla		Buttercup			Cahuilla	
Sep. 02	0.25	0.82	1	0.25	10th	3	0.76	10th
Oct. 02	0	0.06	0		-	1	0.06	26th
Nov. 02	0	0.03	0		-	3	0.01	27, 29, 30
Dec. 02	0	0.01	0		-	1	0.01	1st
Jan. 03	0.01	0	1	0.01	8th	0		-
Feb. 03	0.81	1.26	3	0.41	12th	4	0.57	12th
Mar. 03	0.08	0.5	2	0.05	15th	2	0.32	16th
Apr. 03	0	0	0		-	0		-
May 03	0	0	0		-	0		-
Jun. 03	0	0	0			0		
Jul. 03	0.03	0.06	1	0.03	28th	1	0.06	30th
Aug. 03	0.36	0.63	2	0.31	24th	3	0.46	24th
Sep. 03	0	0	0			0		
Oct. 03	0	0	0			0		
Nov. 03	0.26	0.11	1	0.26	12th	1	0.11	12th
Dec. 03	0	0.01	0			1	0.01	25th
Jan. 04	0.11	0.05	2	0.09	22nd	1	0.05	20th
Feb. 04	0.55	1.21	1	0.55	23rd	4	1.15	22nd
Mar. 04	0.20	0.23	2	0.18	2nd	2	0.14	2nd
Apr. 04	1.34	0.59	1	1.34	2nd	2	0.58	2nd
May 04	0	0	0			0		
Jun. 04	0	0	0			0		
Jul. 04	0	0	0			0		
Aug. 04	0.85	0.47	1	0.85	14th	1	0.47	14th
Sep. 04	0	0.36	0			1	0.36	19th
Oct. 04	1.30	0.88	3	0.84	21st	4	0.51	21st
Nov. 04	0.20	0.52	3	0.11	22nd	2	0.41	21st
Dec. 04	0.83	0.85	3	0.73	6th	4	0.80	6th
Jan. 05	0.77	0.80	5	0.35	4, 26	5	0.44	4th
Feb. 05	1.06	1.46	5	0.71	17th	5	1.17	17th
Mar. 05	0.47	0.35	1	0.47	5th	1	0.35	5th
Apr. 05	0.05	0	1	0.05	24th	0		
May 05	0	0	0			0		

Source: California Dept. of Water Resources, 2003-05.

Table 8. Precipitation records at two RAWS stations in the Algodones Dunes, September 2002-May 2005. Shaded areas indicate growing season.

The total precipitation at the Buttercup RAWS during the 2004-05 growing season was 4.68 inches, while the Cahuilla RAWS station recorded 4.86 inches. This contrasts with 2002-03 and 2003-04 when Buttercup received 0.90 and 2.46 inches, respectively, and Cahuilla recorded 1.41 and 2.20 inches. As shown in Table 8, most of the precipitation in 2002-03 and 2003-04 occurred in the late winter and spring period between February and April. Seasonal variation in rainfall, and thus in germination and growth, varies widely, with more than a 500% difference between 2002-03 and 2004-05.

The link between rainfall and germination is shown in Figures 5 and 6. The blue precipitation fields are cumulative precipitation at the Buttercup and Cahuilla RAWS weather stations. For the purposes of this study, we have defined the growing season as October through April, and the dormant summer season as May through September.

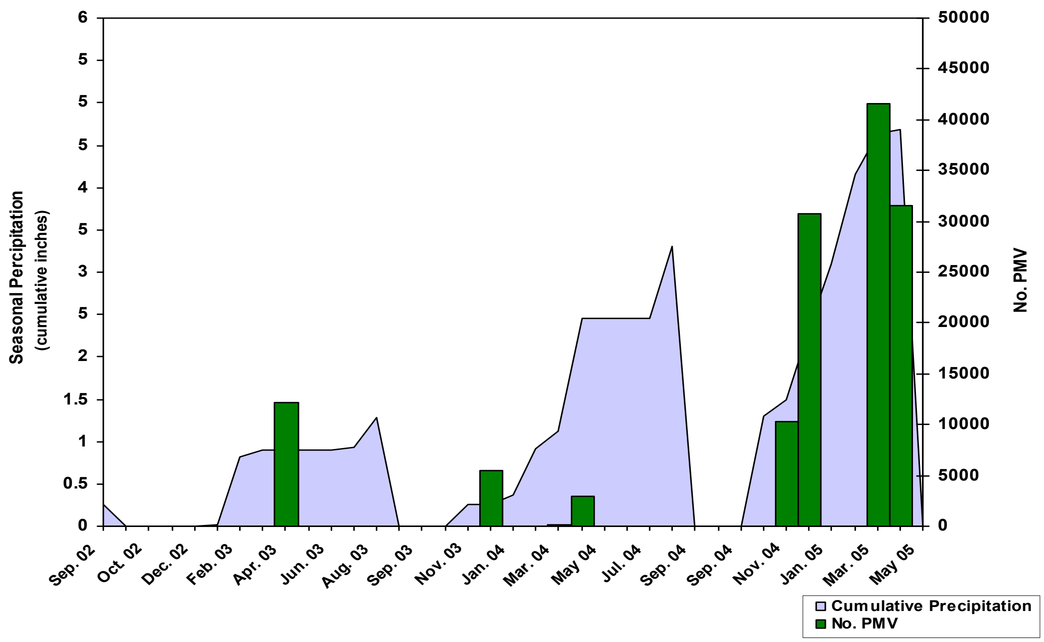


Figure 5. Seasonal precipitation v. seedling counts at 7 Buttercup sample sites 2002-05

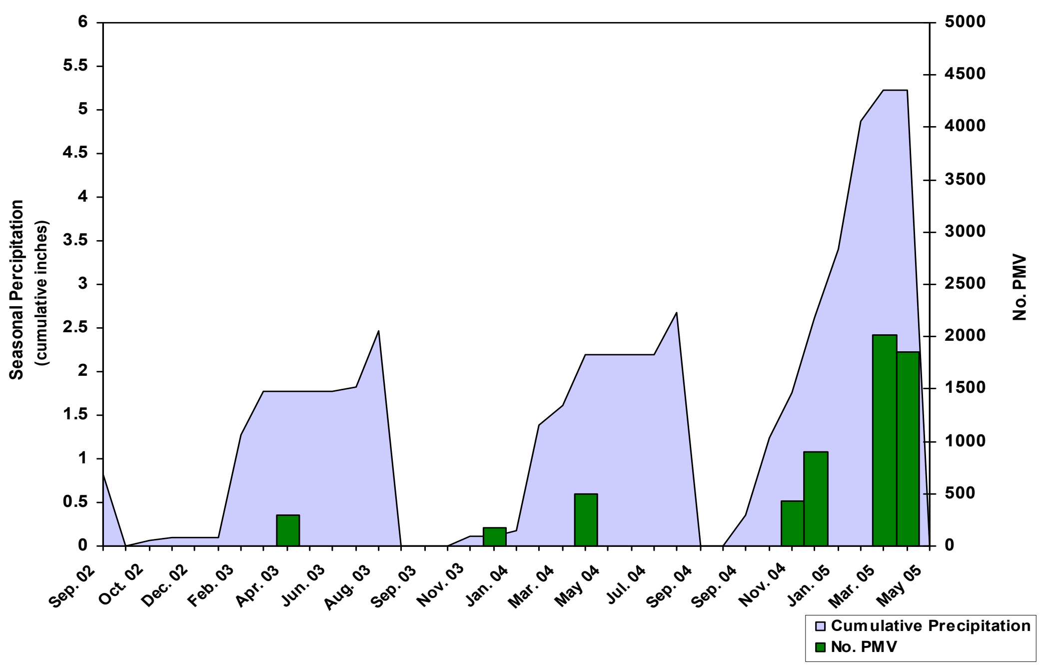


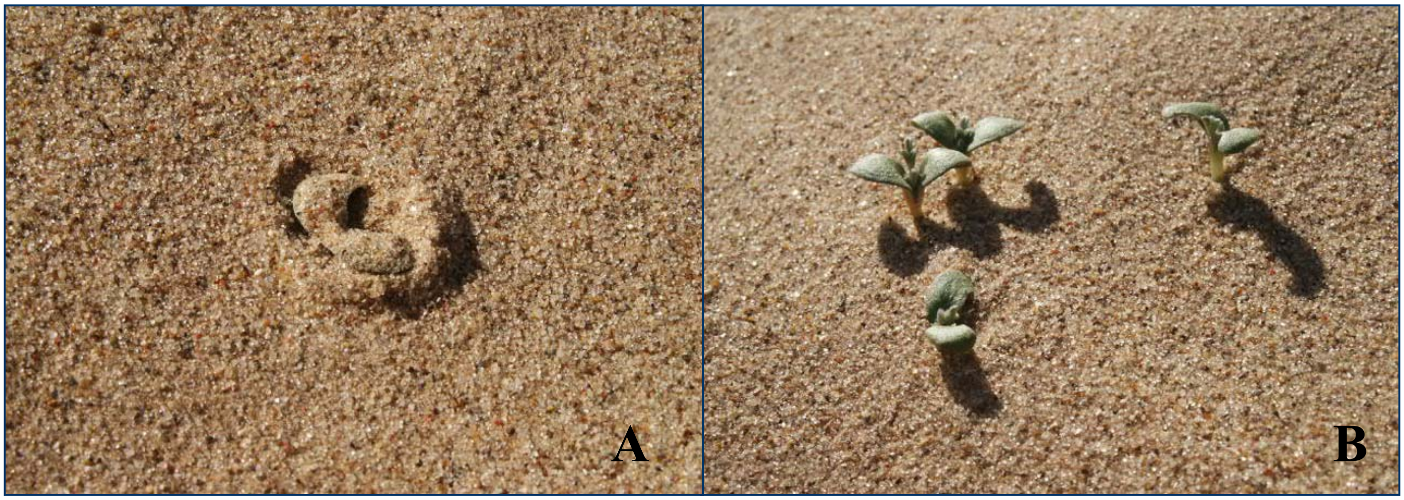
Figure 6. Seasonal precipitation v. seedling counts at 6 Glamis sample sites 2002-05

The cumulative precipitation totals are reset in our diagrams as of 1 October each year. (The actual cumulative figures from the RAWS stations are reset annually on November 16th.) The green bars represent plant counts at each visit for seven study sites at Buttercup and six sites at Glamis (near the Cahuilla RAWS). Patton Valley site data is not included as there is no nearby weather station.

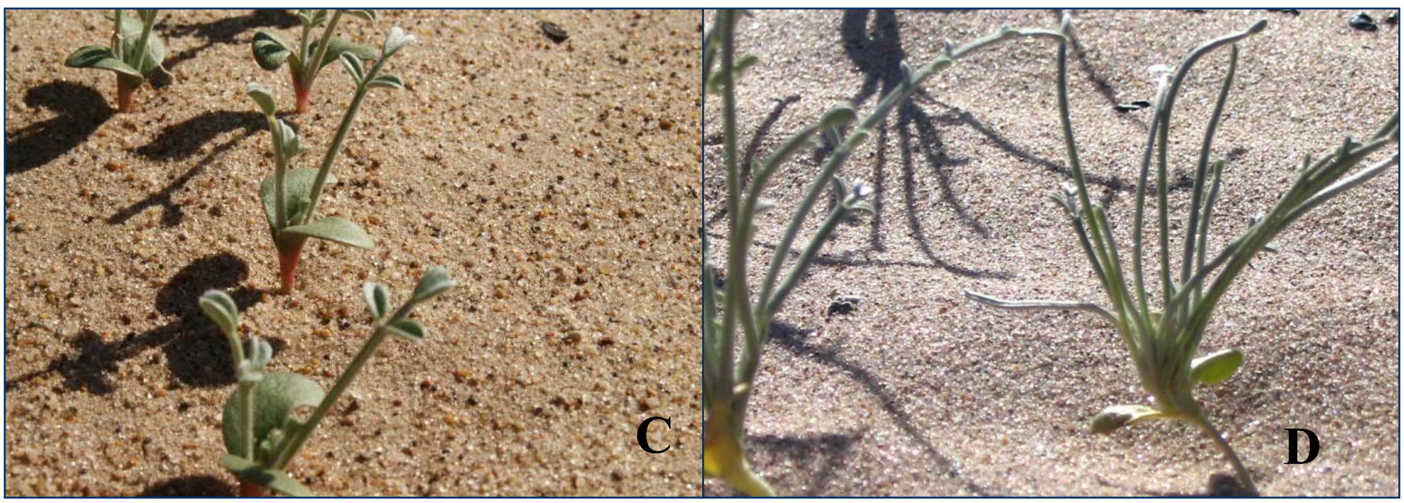
The first significant precipitation in the 2002-03 growing season occurred February 12-14, when 0.81 inches was recorded at Buttercup and 1.26 inches fell at Cahuilla. This resulted in a germination event which, at the 25 sample sites, was 10% greater than at those sites in 2000-01. Summer rains on September 10th (0.25 in at Buttercup and 0.82 in at Cahuilla) were apparently too late to aid in survival; only 0.3% of the February cohort was still alive in December 2003. There was no new germination in response to the September rainfall.

The first rain of the 2003-04 growing season occurred on November 12th, when 0.26 in fell at Buttercup and 0.11 in was recorded at Cahuilla. The winter was quite dry until a storm in late February. Germination resulting from this event was less than in November and less than in February 2003, although the reason was not clear (Phillips and Kennedy 2004). An early April rainfall comparable in magnitude to the February storm resulted in no additional germination, leading to the conclusion that seeds do not germinate after late rains, probably a temperature-driven response that prevents seeds from germinating so late in the season that they would have no chance to develop enough to survive the approaching summer. Rains in mid-August of up to 0.85 in apparently replenished soil moisture enough to result in a survival rate of 12% to the fall of 2004, but resulted in no new germination.

The magnitude of the precipitation year in 2004-05 and the germination event it caused is shown clearly in Figures 5 and 6. By mid-March nearly 78,000 first-year plants were counted, more than twice as many first-year plants as were counted in any previous census at the 25 sites, and at some sites many of these were already in fruit. The smooth slope of the cumulative rainfall curve in Figures 5 and 6 shows that the season was not punctuated by dry spells (plateaus) as in the previous two seasons. The sand was continuously wet a couple of cm below the surface all winter, and this apparently accounts for nearly continuous germination throughout the season, or at least between November and December, and between December and March. Germination appears to occur over a period of time rather than as a single flush immediately following rains. It seems likely that seeds germinating some period of time after a rain probably are buried rather than lying on the surface. It is not known if seeds germinated during mid-winter, as no observations were made in January and February. A six-week dry spell with associated warm temperatures and high winds resulted in a decrease in the number of first-year plants counted in April. Most of the first-year plants that were in fruit in March had shed their pods in April; many of these as well as some of the pre-reproductive plants were dead in April.



Life history of *Astragalus magdalenae* var. *peirsonii*
from initial emergence (Plate A), to seedlings (Plates B, C and D), and finally to fully reproductive first-year plants (Plate E)



Photos by A. M. Phillips, III, D..J. Kennedy, and D. Roth

CONCLUSIONS

The 2004-05 season provided conclusive evidence that the population of *Astragalus magdalenae* var. *peirsonii* in open areas of the Algodones Dunes is healthy and thriving. Overall, the population level in 2004-05 was over twice as high as in 2001, the first year of the study. Rainfall patterns during each of the five years of our study have been different, and our annual counts of plants compared with climate data show with certainty that population is more strongly tied to amount and timing of rainfall events than any other factor, natural or man-made.

Our assertion that first-year Peirson's milkvetch plants that germinate in the fall can and do reach reproductive maturity during their first growing season was validated in 2005 when some 20,000 first-year plants were documented as fertile. The seedlings had been followed since November, and an inventory of perennial plants made in December 2004 was used as a baseline of older plants. The claims that only second-year and older plants are reproductive, and that we misidentified age classes of plants in 2001, were shown to be without merit by our 2004-05 study.

Although we did not keep track of numbers of OHV-affected plants during the 2004-05 study, data made available by BLM was consistent with our figures in 2001 and 2003. BLM (2005) estimated 0.3% of all plants showed evidence of OHV damage dunes wide. The density of affected plants was highest at Glamis (0.103 plants/ha) and Buttercup (0.096 plants/ha) and lowest (0.000) in the wilderness area and Adaptive Management Area (approximately the large central closure). It should be noted that the BLM Buttercup transects missed the area of greatest milkvetch density, where five of our six study sites are located. These OHV impact figures compare with our estimates of 0.93% in 2001 and 1.3% in 2003.

An interesting observation in 2004-05 was that Peirson's milkvetch plants were more widely distributed in the dunes than in other years, with low-density occurrences often observed between sites where no plants had occurred before. This shows that a dormant seed bank is widely present in the dunes, probably deposited by windblown pods that were blown beyond optimal sites. The long period of wet sand in 2004-05 meant that there was less sand movement, and areas that usually experience heavy abrasion by blowing sand and high rates of sand deposition or erosion were more stable. This apparently allowed seedlings to become established outside their normal distribution. This was noted mainly between sites of known occurrence, not in the unvegetated "high dunes" where more sand movement and most OHV use are concentrated.

We conclude that the population of *A.* m var. *peirsonii* in the Algodones Dunes is vibrant, healthy, and responsive to climatic events that promote germination. It is able to remain dormant by means of a healthy seed bank when conditions are unfavorable, and it coexists successfully with current patterns and levels of use by OHVs and, we believe, with any projected future use levels without the need for Endangered Species Act protection. We are unaware of any scientific, documented evidence to the contrary.

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Appendix A
Summary of actual plant counts at 25 sample sites, stratified by location, 2001 – 2005

ASA PMV Study Sites - Nov. 2004-Apr. 2005
Algodones Dunes (ISDRA), California

Site No.	Loc.	# Plants Spring 01	# Nov.03-Mar.04 Sdl. Apr. 04	#03-04 Survivors Dec. 04	#New Seedl. Nov. 04	#New Seedl. Dec. 04	#2004-05 Plts. Mar. 05	#2004-05 Plts. Fertile Mar. 05	#2004-05 Plts. Apr. 05	#2004-05 Plts. Fertile Apr. 05
6	Butrcup	340	0	0	55	207	208	187	157	62
7	"	3,127	1,465	126	5,535	18,880	24,681	12,274	17,982	3,420
21	"	1,327	82	3	700	1,842	2,175	1,054	2,203	580
22	"	807	49	5	400	824	634	476	837	460
23	"	2,800	26	0	215	2,894	1,525	862	3,186	966
28	"	978	530	21	1,300	2,400	4,364	3,172	2,292	899
29	"	3,994	732	33	1,860	3,750	8,039	4,934	4,893	909
32	Pat. Vly.	657	747	51	245	1,604	2,769	1,931	4,052	1,662
34	"	1,534	85	20	1,500	2,845	2,748	2,419	3,221	1,023
41	"	120	546	132	525	1,795	2,286	1,453	2,960	1,026
44	"	798	105	8	0	175	797	572	818	434
46	"	1,531	1,646	176	1,750	3,050	6,662	3,985	4,326	1,073
47	"	2,530	585	73	1,100	3,831	3,424	2,129	3,001	1,314
48	"	1,037	289	25	225	2,165	2,531	1,211	2,248	943
51	"	1,898	778	128	418	2,074	3,255	2,947	2,859	860
52	"	3,010	214	36	500	3,009	3,465	2,470	3,398	1,300
53	"	1,090	140	54	314	545	932	840	1,046	370
54	"	577	501	163	1,600	2,115	1,632	1,420	2,406	491
57	"	1,967	842	67	200	918	3,783	3,226	3,188	1,053
13	Glamis	230	272	47	100	610	1,712	1,238	1,543	990
15	"	28	0	0	1	28	30	22	19	14
16	"	265	0	0	114	92	95	48	90	24
19	"	77	214	0	15	79	117	64	170	62
60	"	88	5	0	30	40	18	7	11	3
61	"	41	0	0	125	46	40	17	25	7
		30,851	9,848	1,168 (11.9%)	18,827	55,818	77,922	48,958 (62.8%)	66,931	19,945 (29.8%)

Appendix B
In-field data form, March 2005

Algodones Dunes Rare Plant Surveys

Peirson's Milkvetch

Astragalus magdalenae* var. *peirsonii

March 2005

Site No. ______________ Area 1 2 3 Date ____________________

Investigators ____

****

Feb.- Mar. 2005 seedlings present? YES NO

No. of Feb.-Mar 05 seedlings __________________________________

No. of fall 04 plants ____

No. of fall 04 plants reproductive ___________________________

No. of clusters ____________________ List new GPS waypoints below

No. of perennial survivors _________________________________

No. of perennial survivors reprod. _______________________

New cluster waypoints created:

Appendix C
In-field data form, April 2005

Algodones Dunes Rare Plant Surveys

Peirson's Milkvetch

Astragalus magdalenae* var. *peirsonii

April 2005

Site No. ______________ Area 1 2 3 Date ____________________

Investigators ____

****

Mar.-Apr. 2005 seedlings present? YES NO

Total no. of plants ____

Total no. plants reproductive _______________________________

No. of clusters ____________________ List new GPS waypoints below

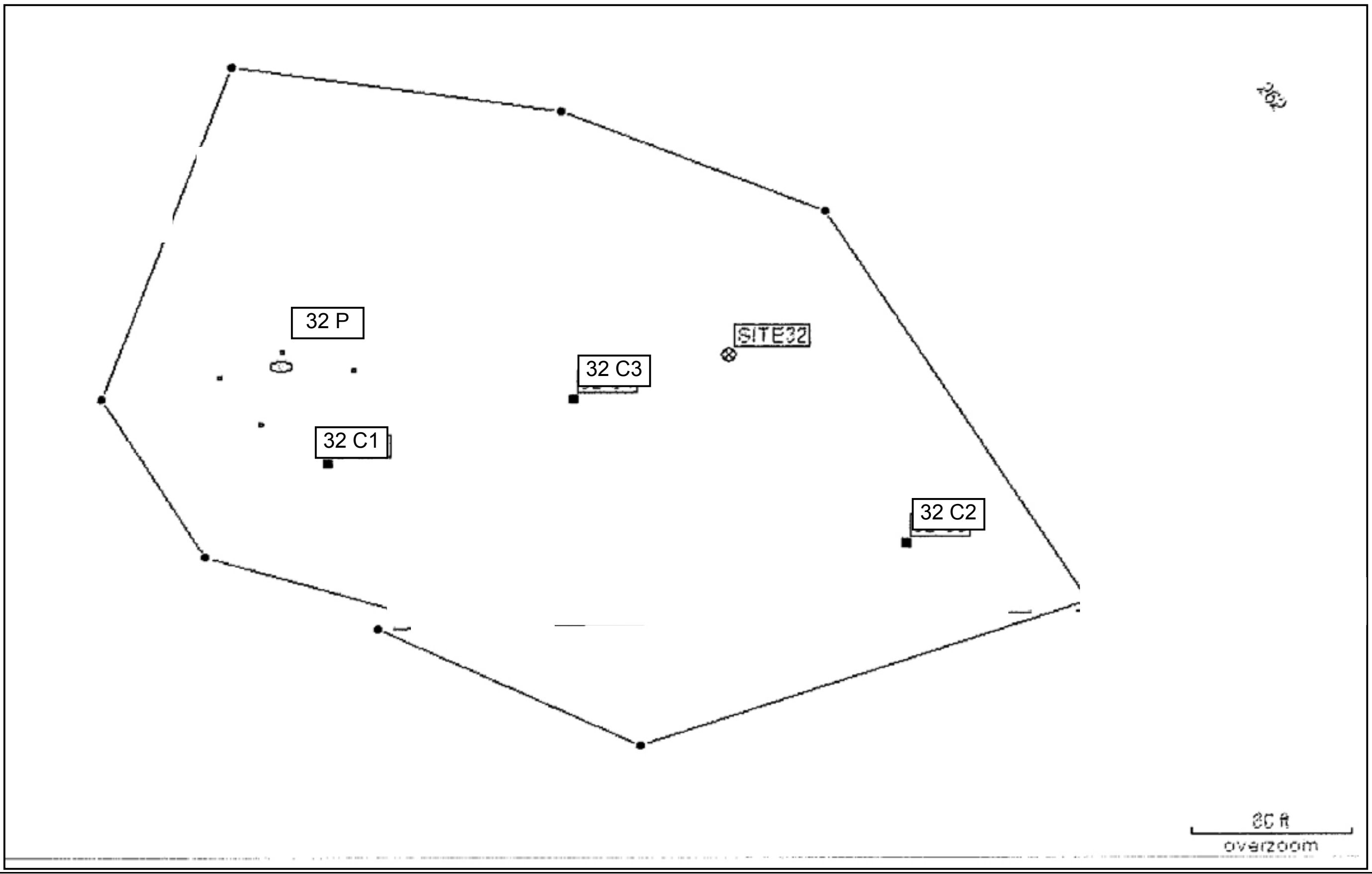
Cluster plant counts: ____

____

____

New cluster waypoints created:

Appendix D
In-field data form (used to survey plant clusters), April 2005



SITE 32 – GPS Waypoints			
	Date Created	***Name/Description***	***In/Near***
CLUSTERS	Feb 2002	32 P/ seed bank cluster	
	Feb 2002	32 C2/ PMV cluster	
	Feb 2002	32 C3/ PMV cluster	
	Feb 2002	32 C4/ PMV cluster	
OLD DATA	Dec. 2003	32 L 01/ 2001 survivor (missing in 3/05)	In 32 C2
	Dec. 2003	32 L2 01/two 2001 survivors (missing in 3/05)	In 32P
	Dec. 2003	32 L 001/2001 survivor (missing in 3/05)	In 32P
	Dec. 2003	32 L 0001/2001 survivor (missing in 3/05)	In 32 C2
	Dec. 2003	32 PODS 27/ pod cluster (27 pods)	In 32 C3
	Dec. 2003	32 SDS 50/ seed cluster (50 seeds)	In 32 C3
	Nov. 2004	SITE 32 CL1 NOV04/ PMV cluster	In 32 C2
NEARBY			
NEW			